Does Energy Intensity Contribute to CO2 Emissions? A Trivariate Analysis in Selected African Countries

muhammad Shahbaz and Sakiru Adebola Solarin and Rashid Sbia and Sadia Bibi

COMSATS Institute of Information Technology, Lahore, Pakistan, Multimedia University Malaysia, Melaka, Malaysia, Solvay Brussels School of Economics and Management, Belgium, COMSATS Institute of Information Technology, Vehari, Pakistan

8. January 2015

Does Energy Intensity Contribute to CO_2 Emissions? A Trivariate Analysis in Selected African Countries

Muhammad Shahbaz
Department of Management Sciences,
COMSATS Institute of Information Technology,
Lahore, Pakistan. Email:shahbazmohd@live.com
Cell:+92-334-3664-657, Fax: +92-42-99203100

Sakiru Adebola Solarin
Room 5012, Faculty of Business,
Multimedia University Malaysia, Melaka, Malaysia
Email: sasolarin@mmu.edu.my

Rashid Sbia
DULBEA, Solvay Brussels School of Economics and Management,
Belgium. Email: Rashid.Sbia@ulb.ac.be

Sadia Bibi
Department of Management Sciences, COMSATS Institute of Information
Technology, Vehari, Pakistan. Email: sadiabibi@ciitvehari.edu.pk

Abstract:
The present study investigates the dynamic relationship between energy intensity and CO_2 emissions by incorporating economic growth in environment function using data of Sub Saharan African countries. For this purpose, we applied panel cointegration to examine the long run relationship between the series. We employ the VECM Granger causality to test the direction of causality between the variables.

At panel level, our result validates the existence of cointegration among the series. The long run panel results show that energy intensity has positive and statistically significant impact on CO_2 emissions. There is also positive and negative link of non-linear and linear terms of real GDP per capita with CO_2 emissions supporting the presence of environmental Kuznets curve (EKC). The causality analysis reveals the bidirectional causality between economic growth and CO_2 emissions while energy intensity Granger causes economic growth and hence CO_2 emissions, while across the individual countries, the results differ. This paper opens up new insights for policy makers to design comprehensive economic, energy and environmental policy for sustainable long run economic growth.

Keywords: Economic Growth, Energy Intensity, CO_2 Emissions, Africa

1. Introduction

In addition to being the greatest market failure the world has ever experienced, climate change has been described as a serious environmental threat of 21st century (Stern, 2006). The adverse impacts of climate change impose an additional cost on vulnerable countries to achieve their development goals. The channels in which climate change affects GDP includes lower productivity; damages from catastrophic storms and sea level rise; rising agricultural and forestry losses; growing food and water shortages; and massive refugee problems (Stern, 2006). Among the greenhouse gasses (GHGs) that are responsible for the current global warming, CO_2 emissions is by far the most significant, as it contributes more than 70% of atmospheric concentration (Solarin, 2014a). Human activities are chiefly responsible for CO_2 emissions in several instances. Pursuits of economic activities involve fuel combustion in the power generation, industrial, residential and transportation sectors, which add to GHGs. Recently, there has been increasing scrutiny of the environmental consequences of economic growth. Hence, the benchmark of economic activities growth is gradually shifting from simple growth to eco-friendly growth in the last couple of decades (Nasir and Rehman, 2011).

Resulting from the perceived relationship between emissions and economic growth on the one hand and emissions and energy (which is responsible for most emissions and also serve as engine of economic growth and development in many countries), on the other hand, literature has traditionally considered environmental degradation, economic growth and energy consumption within the Environmental Kuznets curve (EKC) framework. It postulates that pollutant emissions increase with income in lower income countries but decrease with income in higher income countries (Solarin, 2014a, b). There are several studies for different economic blocs. However, the findings from these papers are not only diverse but also, largely ignore African countries. Martinez-Zarzoso and Bengochea-Morancho (2004) investigated the emissions and income relationship and established the incidence of the EKC in 22 OECD countries. Using the data of six Central American countries, Apergis and Payne (2009) investigated the relationship between economic growth, energy consumption and CO_2 emissions. The results suggested the existence of EKC in the six Central American countries. The findings further showed that short run unidirectional causality runs from economic growth and energy use to emissions and long run bidirectional causality between energy consumption and CO_2 emissions. Lean and Smyth (2010) applied trivariate model to examine the relationship between CO_2 emissions, electricity consumption and economic growth in the case of ASEAN countries, with the test statistics providing support for the EKC hypothesis. Their results further indicated that electricity consumption and CO_2 emissions Granger cause economic growth. Hossain (2011) investigated the causality between CO_2 emissions, energy consumption and economic growth for nine newly industrialized countries (NIC). The empirical results reported short run causality flowing from economic growth to energy consumption and from energy consumption to CO_2 emissions. Pao and Tsai (2011) used the data of Brazil India China and Russia (BRIC) to investigate the dynamic relationship between economic growth, energy consumption and carbon emissions. The study provided evidence for EKC in the BRIC countries. Their results further supported the feedback hypothesis between economic growth and CO_2 emissions and, energy consumption and economic growth. Akhmet et al. (2014) utilized the data South Asian Association for Regional

Cooperation (SAARC) countries to examine the relationship between energy consumption and CO_2 emissions. They found that energy consumption Granger causes CO2 emissions in most of the SAARC countries. Khan et al. (2014) examined the causality between energy consumption and CO_2 emissions, while using the global level data and found unidirectional causality running from energy consumption to CO_2 emissions[1].

We extend the existing literature by exploring the dynamic link in emissions, energy intensity and economic growth link for 13 African countries over the period 1980-2012. This paper contributes to the current literature in several ways. According to our knowledge, this is the first multi-country study on the determinants of emissions in Africa, within the EKC framework. The EKC framework is relevant as African countries are largely low income economies, which face the twin trajectories of increase in emissions and near-consistent economic growth. Therefore, it is important to consider what will happen to CO_2 emissions, at higher level of income based on the current trend. Against the majority of the existing literature, we employ energy intensity as a proxy for energy use as against the norm of energy consumption per capita because energy intensity is a better measure than energy consumption per capita because energy use is affected, to a large extent, by the output per capita. Measuring energy production and use per unit of gross domestic product (GDP) controls for the effect of country income. The study further contributes to the existing literature by utilizing both panel-based methods as well as time series approaches, unlike in the previous papers, which have used either of the method. While time series methods have the advantage of capturing individual characteristics of each country better, thus more informative, panel-based cointegration and causality methods are less susceptible to problems

[1] In some single-country analyses, Shahbaz et al. (2012); Shahbaz et al. (2013a, b, c,d) Shahbaz et al. (2014) also provided evidence for the empirical existence of the EKC for Pakistan, Romania, Turkey, Portugal, Malaysia, and Bangladesh respectively.

associated with short span of data thus generating more degrees of freedom, more variability, and therefore better efficient estimates. The remainder of the paper is prepared as follows. Section-2 deals with a brief overview of CO_2 emission in Africa. Econometric modelling and estimation techniques as well as the empirical findings are discussed in Section-3. Section 4 contains conclusions and policy recommendations.

1. A Brief Overview of CO_2 Emission in Africa

Although, Africa accounts for very low share of global CO_2 emissions, the region continues to experience upsurge in its emissions rate. The continent accounts for 1.9% of the global emissions in 1973 to the current rate of more than 3%. A typical African country generates 13 times less GHGs than his counterpart in North America (Brief, 2007). North African countries have generated one of the biggest growth rates in global emissions, while South Africa, which depends greatly on coal, accounts for over 65% of the region's entire emissions, which makes it the 11th biggest emitting country in the globe (APF, 2008). The impacts of climate engage, which is mostly felt Africa, ranges from energy shortages, deteriorating food security, spreading infectious disease, increasing migratory burdens and incessant clashes over limited water and land resources (APF, 2008). The continent lost 65% of its arable land between 1950-1990 and likely to lose up to two thirds by 2025 due to land degradation (Aboubacar, 2006). The recurring drought-induced famine in Africa, frequency of heat waves, and heavy precipitation events, which have increased since the 1950s, are fallouts of global warming (Cogan, 2008). However, the continent receives the least attention from global policy makers. One of the reasons given is the lack of studies on African countries (Boko et al. 2007). Due to the insignificant contribution to global emissions, previous studies have largely ignored African countries, which however requires research for the purpose of negotiating multilateral climate change agreements; designing appropriate environmental and energy policies (Solarin, 2014a).

3. Data Collection and Methodological Framework

3.1 Data Collection

We extracted the data of the series including real GDP per capita (US $ at constant prices), energy intensity (energy consumption/GDP) per capita, CO_2 emissions (metric tons) per capita from the world development indicators (CD-ROM, 2013). The time span of study is 1980-2012. We have transformed all the series into logarithmic form. $\ln C_t$ is natural log of CO_2 emissions per capita, $\ln Y_t$ ($\ln Y_t^2$) is for natural log of real GDP per capita (square term of real GDP per capita) and natural log of energy intensity per capita is shown by $\ln E_t$. The countries in sample are Benin, Botswana, Cameroon, Congo Republic, Ethiopia, Gabon, Ghana, Kenya, Nigeria, Senegal, South Africa and Zambia.

3.2 ADF Unit Root Test

The investigation of integrating order of all variables is prerequisite to examine the long run relationship or cointegration relation among the variables. Widely used Augmented Dickey-Fuller (ADF) reveals that inference about basic stochastic process is based on basic time series. This makes stationarity tests necessary to illustrate the unit root problem in empirical analysis. The results of ADF unit root test are reported in Table-1, which shows that CO_2 emissions ($\ln C_t$), economic growth ($\ln Y_t, \ln Y_t^2$) and energy intensity ($\ln E_t$) are non-stationary at level. The entire variables are established as integrated at I(1). This shows that all the series have unique level of integration. Following unique order of integration, we can apply Johansen and

Juselius (1990) multivariate framework cointegration approach to examine the long run relationship between the variables.

TABLE 1 ABOUT HERE

3.3 Johansen Cointegration Test

In this study, Johansen maximum likelihood (ML) approach that was advanced by Johansen and Juselius (1990) and Johansen (1995) is employed to estimate cointegration among variables. The main reason is that Johansen cointegration is one of the most consistent tests of cointegration. The other advantage of this approach is that one can simultaneously examine several cointegration relationships among the variables. Two statistics are used for this cointegration test, which are the trace (Tr) test and the maximum eigen value (λmax) test. The results of Johansen cointegration are reported in Table-2. We find that two (one) cointegrating vectors are found in Botswana, Congo Rep., Ethiopia, Gabon and Senegal (Benin, Cameroon, Ghana, Kenya, Nigeria, Senegal, South Africa, Togo and Zambia). This confirms the presence of cointegration between the variables for the sampled countries.

TABLE 2 ABOUT HERE

TABLE 3 ABOUT HERE

The long run and short run panel elasticities are reported in Table-3. The long run panel results indicate that energy intensity is positively linked with CO_2 emissions and it is statistically significant in case of Botswana, Congo Republic, Gabon, Ghana, South Africa Togo and Zambia. In the remaining countries, impact of energy intensity on CO_2 emissions is positive in

Benin, Cameroon, Nigeria, Senegal (negative in Ethiopia, Kenya) but it is statistically insignificant. The relationship between real GDP capita and CO_2 emissions per capita is non-linear. The linear and non-linear terms of real GDP per capita are positively and negatively linked with carbon emissions per capita. This confirms the empirically presence of Environmental Kuznets curve (EKC) in the case of South Africa, Congo Republic, Ethiopia and Togo. In the case of Senegal, Nigeria and Cameroon, relationship between economic growth and carbon emissions is U-shaped. In most of the countries we could not find the existence of the EKC for carbon emissions. In short run, energy intensity leads CO_2 emissions in case of Benin, Botswana, South Africa, Togo and Zambia. The inverted-U relationship between income and carbon emissions is also confirmed in case of Congo Republic and Ethiopia while in Kenya, this relation is U-shaped.

3.4 The VECM Granger causality approach

Upon the establishment of cointegration, the next step is to test the pattern of causal relationship between energy intensity, economic growth and CO_2 emissions using data of African countries. We employ the vector error correction method (VECM) to estimate causality if the series turn out to be stationary. The VECM is restricted variant of unrestricted VAR (vector autoregressive) and restriction is imposed on the presence of cointegration relationship between the series. All the variables are assumed to be endogenous in the VECM. Within such environment, dependent series is influenced both by the lags of independent variables and its own lags in addition to the error correction term. The VECM in three variables case takes the following form:

$$
\begin{bmatrix} \Delta \ln C_t \\ \Delta \ln Y_t \\ \Delta \ln E_t \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} + \begin{bmatrix} B_{11,1}\ B_{12,1}\ B_{13,1} \\ B_{21,1}\ B_{22,1}\ B_{23,1} \\ B_{31,1}\ B_{32,1}\ B_{33,1} \end{bmatrix} \times \begin{bmatrix} \Delta \ln C_{t-1} \\ \Delta \ln Y_{t-1} \\ \Delta \ln E_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} B_{11,m}\ B_{12,m}\ B_{13,m} \\ B_{21,m}\ B_{22,m}\ B_{23,m} \\ B_{31,m}\ B_{32,m}\ B_{33,m} \end{bmatrix}
$$

$$
\times \begin{bmatrix} \Delta \ln C_{t-1} \\ \Delta \ln Y_{t-1} \\ \Delta \ln E_{t-1} \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_3 \\ \zeta_3 \end{bmatrix} \times (ECM_{t-1}) + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \end{bmatrix} \qquad (3)
$$

where u_{it} are residual terms, which satisfies the classical assumptions. Causal relation in the long run is captured by a significance of lagged *ECMs* using t test while F-statistic or Wald test captures short run causality. The VECM is ideal in testing the causality once the variables are cointegrated and there is at least a causal relation. Further, VECM aids in distinguishing between long-and-short runs causal relationships. Besides, the VECM is utilized to determine causality in long run and short run.

The significance of the coefficient of lagged error term i.e. ECT_{t-1} with negative sign supports the presence of long run causal relation using the t-statistic. Short run causal relation is demonstrated by the combined χ^2 significance of the estimates of lagged independent variables. For example, the significance of $B_{22,i} \neq 0 \forall_i$ implies that economic growth Granger causes CO_2 emissions and causality runs from CO_2 emissions to economic growth can be shown by the significance of $\beta_{12,i} \neq 0 \forall_i$. The same conclusion can be inferred for the other causality hypotheses. The results are reported in Table-4. In long run, unidirectional causality running from economic growth to CO_2 emissions in the case of Benin, Cameroon, Congo Republic, Gabon, Ghana, Kenya, Niger, Senegal and Togo. Economic growth Granger causes CO_2 emissions and in return, CO_2 emissions Granger cause economic growth i.e. feedback effect in the case of Botswana, Ethiopia and Zambia. Energy intensity Granger causes CO_2 emissions in the case of Congo Republic, Ethiopia, Gabon, Kenya, Senegal and Togo. The unidirectional causal relationship exists running from CO_2 emissions to energy intensity in South Africa. Evidence for two-way causality is established between energy intensity and CO_2 emissions in Benin, Botswana, Cameroon, Ghana, Nigeria and Zambia. The unidirectional causality running from economic growth to energy intensity (energy intensity to economic growth) is found in case of Benin, Cameroon, Ghana, Nigeria and South Africa (Congo Republic and Ethiopia). The feedback effect between energy intensity and economic growth exists in the case of Botswana and Zambia.

TABLE 4 ABOUT HERE

In short run, the VECM Granger causality reveals that energy intensity Granger causes CO_2 emissions in Benin. The findings show two-way causality between energy intensity and CO_2 emissions in case of Botswana. In case of Congo Republic, energy intensity and CO_2 emissions Granger cause economic growth. One-way causality is found flowing from energy intensity to CO_2 emissions and economic growth and economic growth is Granger cause of CO_2 emissions. Energy intensity is Granger caused by economic growth. In case of Ghana, CO_2 emissions are Granger caused by economic growth. Economic growth and energy intensity Granger cause CO_2 emissions but energy intensity is Granger cause of economic growth. The unidirectional causality exists running from energy intensity to CO_2 emissions. The feedback effect exists between economic growth and CO_2 emissions in the case of Senegal. In South Africa, there is two-way causality between CO_2 emissions and economic growth but energy intensity Granger causes CO_2 emissions. Energy intensity Granger causes CO_2 emissions in the case of Togo. The bidirectional causality is found in the case of Zambia between energy intensity and CO_2 emissions.

3.5 Panel Unit Tests

In the present study, the Levin et al. (2002) or LLC (2002), Im, Pesaran and Shin, (2003) or IPS (2003), Maddala and Wu (1999) or MW (ADF), Maddala and Wu (1999) or MW (PP) and Breitung panel unit root test are used to test the stationarity properties of the variables. The utilisation of panel data in unit root testing is inspired by the benefit of an improved power over that of single equation tests. The results of three panel unit root tests are reported in Table-5.

TABLE 5 ABOUT HERE

We find that the entire series show unit root problem at level with intercept and trend confirmed by LLC, IPS and MW unit root tests. The variables are found to be stationary at first difference. It implies that all the series are integrated at I(1). The unique order of integration of the variables leads us to apply panel cointegration to investigate long run relationship between the variables.

4. Panel Cointegration Tests

Once variables are integrated at unique level of integration i.e. I(1) then cointegration tests are applied to examine whether long run relationship between the variables exists or not. Various tests of cointegration are available, for example Maddala and Wu (1999), Kao (1999) and

Pedroni (2004). In the present study, we apply Pedroni (2004) due to its popularity. The empirical equation of Pedroni (2004) cointegration tests is modelled as following:

$$\ln C_{it} = \psi_{it} + \gamma_i t + \psi_{1t} \ln Y_{it} + \psi_{3t} \ln Y_{it}^2 + \psi_{3t} \ln E_{it} + \mu_{it} \qquad (11)$$

Here $i = 1,2,......., N$ indicates the each country of panel and $t = 1,2,......., N$ denotes the time period to be used in the panel. Pedroni panel cointegration test consists of those cointegration tests which include four panel statistics and three group statistics. There is cointegration between the variables if these statistics may reject the hypothesis of no cointegration. The results of Pedroni cointegration tests are detailed in Table-6.

TABLE 6 ABOUT HERE

The results of panel cointegration are represented in Table-6. The results reported by Pedroni panel cointegration approach revealed that null hypothesis of no cointegration between the variables of panel may be rejected following four panel statistics of panel. These statistics are statistically significant at 5%, 10%, 1% and 1% levels respectively. The results of group cointegration tests showed that only $\sigma - statistic$ accepts the hypothesis of no cointegration while the remaining two statistics i.e. $\rho\rho - statistic$ and ADF-statistic reject the hypothesis of cointegration. This implies that $\sigma - statistic$ has lower power of significance. The rest statistics support to conclude that there is a cointegration. It indicates the presence of long run relationship between the variables.

We apply Johansen Panel cointegration test introduced by Larsson et al. (2001) to test the robustness of long run results. This test of cointegration can be applicable if the variables are found to be stationary at first difference. This test of cointegration is average of individual likelihood ratio cointegration rank trace test statistics attained from individuals in the panel. The multivariate cointegration trace test of Johanson (1995) investigates the each individual cross-section system independently by letting heterogeneity in each cross-sectional unit root for the panel. The results are presented in Table-7 and indicate that computed value of likelihood ratio exceeds the critical values at 1% and 5% levels respectively. This leads to infer that there are two cointegrating vector which validate the existence of long run relationship between variables. These findings confirmed that long run results are robust and consistent.

TABLE 7 ABOUT HERE

We have investigated the long run as well as short run panel results as reported in Table-8. We discover that energy intensity is positively linked with energy pollutants. The relationship between income and environment is inverted-U shaped which reveals that level of carbon emissions increases with a rise in per capita, stabilizes and declines once economy achieves its highest level of income. In short run, we note that energy intensity adds in CO_2 emissions significantly. The statistical significance implies that our established cointegration relation is consistent and robust. The negative sign of the lagged error term indicates that the deviations in CO_2 emissions function are corrected by 13.58 and will take 7 years and 4 months to reach equilibrium path.

TABLE 8 ABOUT HERE

4.1 Panel Granger Causality

Granger (1969) argues that there must be causality at least from one direction if variables are cointegrated for long run relationship. The exact knowledge about direction of causal relationship between carbon emissions, energy intensity and economic growth enables policy makers to articulate an inclusive energy policy to endure economic growth by controlling environment from degradation. For this purpose, we apply dynamic error correction model proposed by Granger (1988). The empirical representation of VECM Granger causality approach is modelled as following:

$$\Delta C_{it} = \alpha_{11} + \sum_{p} \alpha_{12} \Delta C_{it-p} + \sum_{p} \alpha_{13} \Delta Y_{it-p} + \sum_{p} \alpha_{14} \Delta Y^2_{it-1} + \sum_{p} \alpha_{15} \Delta E_{it-p} + \sigma_{11} ECM_{it-1} + \mu_{1it} \quad (12)$$

$$\Delta Y_{it} = \beta_{11} + \sum_{p} \beta_{12} \Delta C_{it-p} + \sum_{p} \beta_{13} \Delta Y_{it-p} + \sum_{p} \beta_{14} \Delta Y^2_{it-1} + \sum_{p} \beta_{15} \Delta E_{it-p} + \sigma_{22} ECM_{it-1} + \mu_{2it} \quad (13)$$

$$\Delta Y^2_{it} = \phi_{11} + \sum_{p} \phi_{12} \Delta C_{it-p} + \sum_{p} \phi_{13} \Delta Y_{it-p} + \sum_{p} \phi_{14} \Delta Y^2_{it-1} + \sum_{p} \phi_{15} \Delta E_{it-p} + \sigma_{33} ECM_{it-1} + \mu_{3it} \quad (14)$$

$$\Delta E_{it} = \varphi_{11} + \sum_{p} \varphi_{12} \Delta C_{it-p} + \sum_{p} \varphi_{13} \Delta Y_{it-p} + \sum_{p} \varphi_{14} \Delta Y^2_{it-1} + \sum_{p} \varphi_{15} \Delta E_{it-p} + \sigma_{44} ECM_{it-1} + \mu_{4it} \quad (15)$$

Here C_{it}, $Y_{it}\,(Y^2_{it})$, E_{it} and Δ are carbon emissions per capita, real GDP per capita (squared of real GDP per capita), energy intensity and difference operator of the series. The error correction term is indicated by ECT and p is for lag length of the variables. The lag length of the variables is selected using the Akaike information criterion (AIC). Economic growth and energy intensity i.e. Y_{it}, Y^2_{it} and E_{it} Granger cause CO_2 emissions if null hypothesis of no causality i.e.

$\alpha_{13} = \alpha_{14} = \alpha_{15} = 0, \forall_{ip}$ is rejected using Wald-test. The existence of the two series (Y_{it}, Y_{it}^2) forces us to fix cross-equation restrictions to examine the causal relationship either from C_{it} (E_{it}) to Y_{it} and Y_{it}^2 is confirmed if the null hypothesis $\beta_{12} = 0\forall_{ip}$ and $\phi_{12} = 0\forall_{ip}$ ($\beta_{15} = 0\forall_{ip}$ and $\phi_{15} = 0\forall_{ip}$ is not accepted. In long run economic growth Granger causes carbon emissions if null hypothesis $\sigma_{22} = \sigma_{33} = 0\forall_{ip}$ is rejected which shows that both Y_{it}, Y_{it}^2 react to changes from long run equilibrium.

TABLE 9 ABOUT HERE

The panel causality results are presented in Table-9. The results showed that the feedback hypothesis exists between carbon emissions and economic growth. This implies that environmental quality can be improved but at the cost of economic growth and economic growth is linked with environmental degradation. These findings are consistent with Shahbaz et al. (2013d) who reported bidirectional causality flowing from CO_2 emissions to economic growth for Malaysia. Energy intensity Granger causes CO_2 emissions and economic growth. But, Apergis and Payne (2009) noted the bidirectional causal relationship between energy consumption and carbon emissions in commonwealth of independent states.

In the short run, there is bidirectional relationship between economic growth and carbon emissions. This empirical evidence is not consistent with Hossain (2011) who found causality runs from economic growth to carbon emissions for newly industrialized economies. The feedback effect exists between energy intensity and economic growth. This finding is different with the empirical evidence of Hossain (2011) who found the unidirectional causal relation flowing from economic growth to energy use. Energy intensity and CO_2 emissions Granger cause each other. This finding is contrary to Shahbaz and Leitão (2013) in the case of Portugal.

5. Concluding Remarks and Policy Implications

The aim of present study is three folds: (i) empirical presence of EKC is tested in Africa, (ii) same exercise is conducted for individual countries, and, direction of causal relationship is explored between CO_2 emissions, energy intensity and economic growth over the period of 1980-2012.

In the long run, the relationship between real GDP per capita and carbon emissions is non-linear, at regional level. This validates the empirical existence of inverted-U shaped relationship between economic growth and CO_2 emissions. The hypothesis does not hold in the short-run for the continent. However, in the two time horizons, energy appears as positive and significant factor for the level of emission in the continent. The results further show that long run unidirectional causality running from energy intensity to economic growth, which implies that the continent is energy-dependent and conserving energy as a policy tool (possibility for emission reduction) is not warranted as such move will impair economic growth. As a policy implication, this evidence seems to suggest that higher economic growth is associated with reduction in levels of CO_2 emissions in long run. Therefore, in the course of decreasing emissions, authorities may not need to sacrifice economic growth, especially in the long term. As energy intensity remains fundamental in meeting basic needs and achieving Africa's development goals; and at the same time, the results shows energy as a major factor in emissions, policy makers must cultivate and nurture attitudinal change policy towards energy use in order to achieve a growth-free emission. Africa is challenged with the task of enhancing access to energy while at same time making optimal usage safe energy alternatives. As it stands now, strong commitments to reduce emissions are made by mostly by developed countries and major developing countries as a way of minimizing the negative impact of climate change in the continent. The countries in the region can also contribute their own quota in the course of emission. Africa is endowed with vast renewable and non-renewable sources of energy, which ironically are have not been accorded adequate attention. The use of non-renewable energy, which is associated with emissions, dominates energy consumption in Africa. For instance, the Southern part of the region depends greatly on coal as a source of energy. It is estimated that the continent has 1,750 TWh potential of hydropower and 14,000 MW of geothermal potential with only 7% of Africa's hydropower resources being developed (Deloitte, 2012), while the same figure for geothermal is 0.6% (United Nations, 2009). It is ideal that these resources are increasingly utilized in the course of promoting green economy. Beyond hydropower and geothermal resources, there are other renewable energies such as bio-fuels which can be utilized as sustainable household fuels across the continent. Similarly, since these resources are unequally distributed; regional power trade becoming increasingly imperative to power strategies in the continent. Emissions reduction or reduction of its negative impacts is a responsibility of all, inclusive of the inhabitants of the continents, who are largely uneducated about the nature of climate and the implications of climate change and their respective roles to combat the scourge. Therefore, it is important that public information and education programs are designed (a) to promote knowledge of climate change issues and (b) to guide positive practices to limit or adjust to climate change. All these efforts should be complemented with appropriate policies to stem deforestation (which accounts for almost 17% to 20% of the total emissions) and the land use sector (which accounts for a 73% of total emissions) in the continent (APF, 2009).

Country-level analysis shows that variables are cointegrated for long run relationship over the period of 1980-2012. Moreover, energy intensity is positively with carbon emissions in African countries except for Ethiopia and Kenya. The Environmental Kuznets curve is validated in case of South Africa, Congo Republic, Ethiopia and Togo. Country-wise, the result for South Africa seems to be similar to the panel results. This is not surprising as the country is responsible for two-thirds of CO_2 emissions in Sub-Saharan Africa the energy consumption and of the GDP per capita in the continent (APF, 2008). The country uses some 40% of the total electricity consumed within the continent. Hence, most of the aforementioned policy recommendations such as the implementation of renewable energy as a policy tool are tenable in the country as well. The country's authorities have recently followed this pattern. Over 90% of South Africa's electricity is sourced from coal, which also account for 70% of its total energy mix (EIA, 2013). This dependence on coal is due to the fact that South Africa houses the ninth largest global recoverable coal reserves and holds 95% of the continent's total coal reserves (EIA, 2013). Fossil fuels are considered to be high emitting fuels with coal mostly culpable. This has made the country to become the chief carbon emitter in Africa. Therefore, the reduction of coal content of the energy mix should be the focal point of energy policy aim at addressing emission in the country. Of late, the government of South Africa has commenced initiatives meant to explore shale gas, which is expected to offer the country with a dependable fuel alternative to coal, especially since natural gas produces less emission (EIA, 2013). Attentions are also being paid to the utilization of renewable energy, which was considered as an economic cost. South Africa has lately embarked on a renewable energy programs with strong solar and wind allocations (Deloitte, 2012).

As per other countries, EKC seems not to exist in the long run. With some parameters insignificant yet, the results analysis indicate that energy consumption is positively associated with emissions, except for Ethiopia and Kenya. Definitely, energy use must be re-structured in these countries such that increase in energy intensity does not necessarily translate into higher emissions. Botswana, Congo Rep and Benin are substantially dependent on fossil fuels, which account for roughly 67.11%, 42.87% and 41.55% of their energy mix in 2010, respectively (World Bank, 2013). Promotion of renewable energy would an appropriate tool in the countries. However, for Ghana, Togo, Zambia and Gabon, which already have sizeable renewable energy in their energy mix, efforts to increase this ratio will be well placed in reducing emissions in these countries such as the introduction of low-emission vehicles, particularly in a commercial context; switching to fuels with lower emission factors, possibly including bio-fuels (UNDP, 2013; EIA, 2013). In the recent times, some of these countries have already launched identical initiatives. For example, Ghana has introduced a Renewable Energy Law, which involves a system of tariff. This is augmented by the Strategic National Energy Blueprint for 2006-2020 which pursues the objective of ensuring that renewable energy constitutes 10% of the total energy mix by 2020 (IEA, 2010). The blueprint also intends to use renewable energy technologies in order to attain 30% penetration of rural electrification by 2020 (Briefing, 2012).

Reference

1. Aboubacar, I. 2006. African Regional Workshop on Adaptation Bulletin, 2(1)

2. Akhmet, G., Zaman, K., Shukui, T., Irfan, D. and Khan, M. M. (2014). Does energy consumption contribute to environmental pollutants? Evidence from SAARC countries. Environmental Sciences and Pollution Research, 21 (9), 5940-5951.
3. Apergis, N and Payne, J. E., (2009). CO2 emissions, energy usage, and output in Central America. Energy Policy, 37, 3282-3286.
4. APF (2008). Climate Challenges to Africa: A Call for Action. Report Prepared for 10th Meeting of the Africa Partnership Forum in Tokyo on 7-8 April 2008
5. APF (2009). Climate challenges to Africa: from Bali to Copenhagen Report Prepared for 12th Meeting of the Africa Partnership Forum in Rome on 10 June 2009.
6. Asafu, J., Adjaye, 2000. The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Economics 22, 615–625.
7. Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 2007: Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F.
8. Brief (2007) Climate change and Africa. Africa Partnership Forum (APF) Policy Brief, 1, 1-4 Organisation for Economic Co-operation and Development (OECD) Publication
9. Briefing (2012) Drivers for low carbon development: Case studies from China, Ghana and Ethiopia . Institute of Development Studies: Brighton United Kingdom
10. Cheng, B., 1995. An investigation of cointegration and causality between energy consumption and economic growth. Journal of Energy and Development 21, 73–84.
11. Cheng, B.S., 1999. Causality between energy consumption and economic growth in India: an application of cointegration and error correction modelling. Indian Economic Review 34, 39–49.
12. Cogan, D. (2008). Corporate Governance and Climate Change: The Banking Sector A Ceres Report Available at http://www.ceres.org/resources/reports/corporate-governance-banking-sector
13. Cropper, M. and Griffiths, C., (1994). The Interaction of Population Growth and Environmental Quality. American Economic Review Papers and Proceedings, 84(2), 250–54.
14. Deloitte (2012). The million jobs question Localisation for Renewables in Africa Deloitte; New York.
15. Dickey, D., and Fuller, W. A., (1979). Distribution of the estimates for autoregressive time series with unit root. Journal of the American Statistical Association, 74, 427-431.
16. Edkins, M., Marquard, A., Winkler, H., (2010) South Africa’s renewable energy policy roadmaps. Energy Research Centre, University of Cape Town South Africa
17. EIA, 2013. Analysis Brief. US Energy Information Administration. Washington, DC 20585
18. Engle, R., and Granger, C., (1987). Co-integration and error-correction: Representation, estimation and testing, Econometrica, 55, 251-276.
19. Fodha, M. and Zaghdoud, O., (2010). Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. Energy Policy, 38, 1150-1156.
20. Glasure, Y., (2002). Energy and national income in Korea: further evidence on the role of omitted variables. Energy Economics, 24, 355–365.
21. Glasure, Y., Lee, A., (1998). Cointegration, error correction and the relationship between GDP and energy: the case of South Korea and Singapore. Resource and Energy Economics 20 (1), 17–25.

22. Granger, C., (1969). Investigating Causal Relations by Econometric Models and Cross-Spectral Methods. Econometrica, 37, 424-438.
23. Granger, C., (1988). Causality, cointegration, and control. Journal of Economic Dynamics and Control. 12(2-3), 551-559.
24. Grossman, G., and Krueger, A., (1995). Economic Growth and the Environment. Quarterly Journal of Economics, 353-377.
25. Hettige, H., Lucas, R., and Wheeler, D. (1992). The Toxic Intensity of Industrial Production: Global Patterns, Trends and Trade Policy. American Economic Review Papers and Proceedings, 82, 478-481.
26. Hossain S. (2011). Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanisation of newly industrialized countries. Energy Policy 39: 6991-6999.
27. Im, K.S., Pesaran, M.H., and Shin, Y., (2003). Testing unit roots in heterogeneous panels', Journal of Econometrics, 115, 53–74.
28. Johansen, S and Juselius, K., (1990). Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxford Bulletin of Economics and Statistics, 52, 169-210.
29. Johansen, S., (1995). Likelihood-Based Inference in Cointegrated Vector Autoregressive Models, Oxford University Press, Oxford.
30. Kao, C., (1999). Spurious Regression and Residual-Based Tests for Cointegration in Panel Data. Journal of Econometrics, 90, 1-44.
31. Karanfil, F., (2008). Energy consumption and economic growth revisited: Does the size of unrecorded economy matter?. Energy Policy, 36(8), 3029-3035.
32. Karlsson**,** S., and Lothgren**,** M., **(**2000)**.** On the power and interpretation of panel unit root tests. Economics Letters, 66(3), 249-255.
33. Khan, M. A., Khan, M. Z., Zaman, K. and Naz, L. (2014). Global estimates of energy consumption and greenhouse gas emissions. Renewable and Sustainable Energy Reviews, 29 (1), 336-344.
34. Larsson, R., Lyahagen, J., and Lothgren, M., (2001). Likelihood-based cointegration tests in heterogeneous panels. Econometrics Journal, 4, 109–142.
35. Lean, H., and Smyth, R., (2010). CO2 emissions, electricity consumption and output in ASEAN. Applied Energy, 87(6), 1858-1864.
36. Levin, A., Lin, C-F., and Chu, C-S. J., (2002). Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics, 108, 1–24.
37. Machado, G. V., (2000). Energy use, CO2 emissions and foreign trade: an IO approach applied to the Brazilian case. Thirteenth International Conference on Input–Output Techniques, Macerata, Italy (2000) 21-25 Aug.
38. Maddala, G., and Wu, S., (1999). Cross-country Growth Regressions: Problems of Heterogeneity, Stability and Interpretation', forthcoming in Applied Economics.
39. Martínez-Zarzoso, I. and Bengochea-Morancho, A., (2004). Pooled Mean Group Estimation of an Environmental Kuznets Curve for CO2. Economics Letters 82, 121-126.
40. Masih, A., and Masih, R., 1996. Energy consumption, real income and temporal causality: results from multi-country study based on cointegration and error- correction modeling techniques. Energy Economics 18, 165–183.

41. Mumtaz, K., Zaman, K., Sajjad, F., Lodhi, M. S., Irfan, M., Khan, I. and Naseem, I. (2014). Modeling the Causal Relationship between Energy and Growth Factors: Journey towards Sustainable Development. Renewable Energy, 63, 353-365.
42. Narayan, P., and Singh, B., (2007). The electricity consumption and GDP nexus for the Fiji Islands. Energy Economics 29, 1141–1150.
43. Narayan, P., and Narayan, S., 2010. Carbon dioxide and economic growth: panel data evidence from developing countries. Energy Policy 38, 661–666.
44. Nasir, M. and Rehman, F. (2011). Environmental Kuznets Curve for carbon emissions in Pakistan: An empirical investigation. Energy Policy, 39(3), 1857-1864.
45. Oh, W. and Lee, K. (2004). Energy consumption and economic growth in Korea: Testing the causality relation. Journal of Policy Modeling, 26, 973-981.
46. Ozturk, I., (2010). A literature survey on energy–growth nexus. Energy policy, 38(1), 340-349.
47. Pao, H-T. and Tsai, C-M., (2010). CO2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy, 38, 7850-7860.
48. Pedroni, P., (2004). Panel Cointegration. Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis. Econometric Theory, 20, 597–625.
49. Seldon, T. and Song, D., (1994). Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions? Journal of Environmental Economics and Management, 27, 147-162.
50. Shahbaz, M. and Leitão, N. C., (2013). Portuguese Carbon Dioxide Emissions and Economic Growth: A Time Series Analysis. Bulletin of Energy Economics 1(1), 1-7.
51. Shahbaz. M., Lean, H., and Shabbir, M., (2012). Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. Renewable and Sustainable Energy Reviews, 16, 2947-2953.
52. Shahbaz, M., Mutascu, M., Azim, P., (2013a). Environmental Kuznets curve in Romania and the role of energy consumption. Renewable and Sustainable Energy Reviews, 18, 165–173.
53. Shahbaz, M., Ozturk, I., Afza, T., and Ali, A. (2013b). Revisiting the environmental Kuznets curve in a global economy. Renewable and Sustainable Energy Reviews, 25, 494–502.
54. Shahbaz, M., Hye, Q., Tiwari, A. K. and Leitão, N. C., (2013c). Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. Renewable and Sustainable Energy Reviews, 25, 109–121.
55. Shahbaz, M., Solarin, S. A., Mahmood, H., & Arouri, M., (2013d). Does financial development reduce CO_2 emissions in Malaysian economy? A time series analysis. Economic Modelling, 35, 145-152.
56. Shahbaz, M., Uddin, G. S., Rehman, I., and Imran, K., (2014). Industrialization, electricity consumption and CO2 emissions in Bangladesh. Renewable and Sustainable Energy Reviews, 31, 575-586.
57. Solarin, S. A., (2014a) Convergence of CO_2 emission levels: Evidence from African countries. Journal of Economic Research, 19(1), 65-92
58. Solarin, S. A. (2014b). Tourist arrivals and macroeconomic determinants of CO2 emissions in Malaysia. Anatolia, 25(2), 228-241
59. Stern, N. (2006). Stern Review Report on the Economics of Climate Change. London: HM Treasury.

60. Stock, J. and Watson, M., (1988). Testing for Common Trends. Journal of the American Statistical Association, 83, 1097-1107.
61. UNDP (2013). Clean Development Mechanism Opportunities and Challenges in Zambia. United Nations Development Programme: New York, NY.
62. United Nations (2009). Scaling up Renewable Energy in Africa Paper prepared for 12th Ordinary Session of Heads of State and Governments of the AFRICAN UNION, January 2009 Addis Ababa, Ethiopia.
63. Wang, K-M., (2012). The relationship between carbon dioxide emissions and economic growth: quintile panel-type analysis. Quality & Quantity 2012. DOI 10. 1007/s11135-011-9594-y.
64. World Bank (2013). World Development Indicators on CD-ROM, Washington, DC.
65. Yu., E, and Choi, J. (1985). The causal relationship between energy and GNP: an international comparison. Journal of Energy and Development 10 (2), 249–272.